Deep Learning : Convergence of HPC and Hyperscale

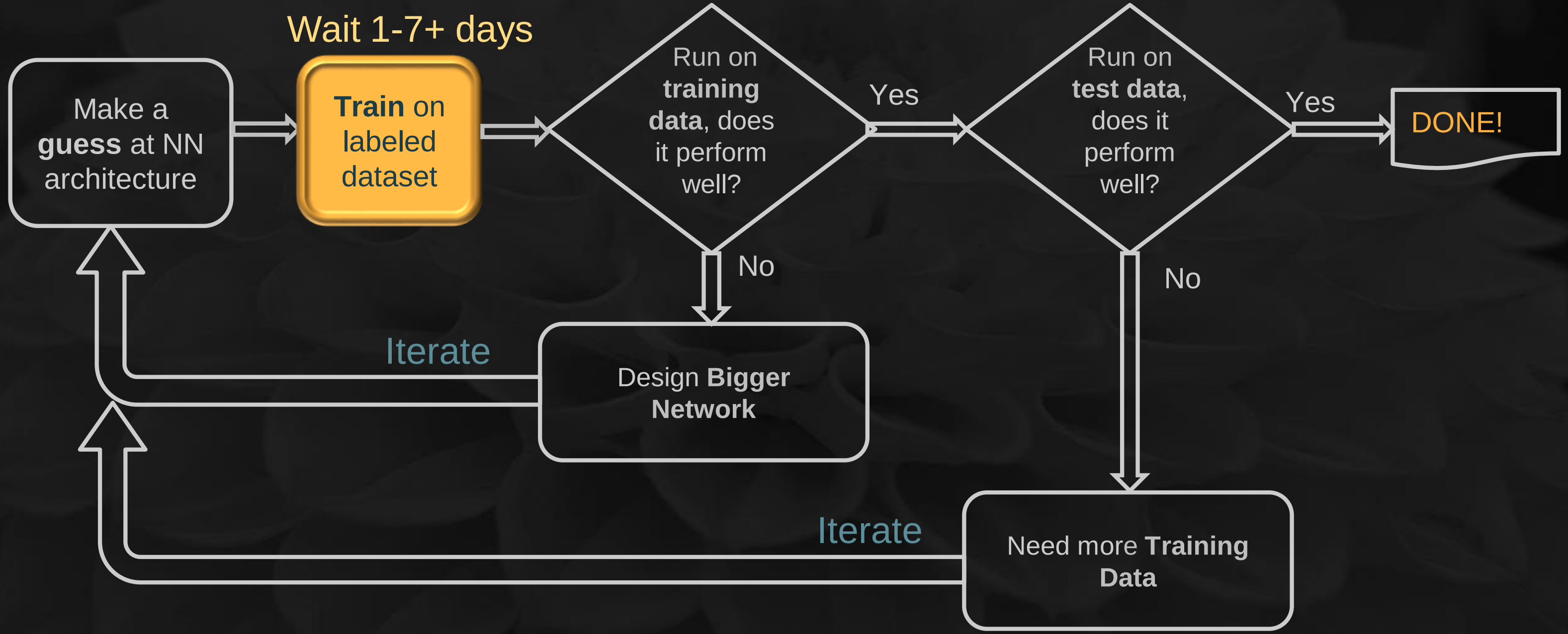
Sumit Sanyal
CEO

minds.ai

Technology Revolution :
Deep Neural Nets

- A new paradigm in programming
  - DNNs remarkably effective at tackling many problems
  - Designing new NN architectures as opposed to “programming”
  - Training as opposed to “compiling”
  - Trained weights as the “new” binaries
- Big Neural Nets required to process Big Data
  - Videos, images, speech and text
  - DNNs are significantly increasing recognition accuracies which have stagnated for decades
  - Used to structure Big Data

Neural network development



Compute vs. IO

- Deep Neural Nets require a lot of compute cycles!
- An example – image classification:
  - Ratio of (Compute cycles : IO bandwidth) significantly higher than non AI algorithms
  - Training AlexNet (for image classification) requires ~27,000 flops/input data byte
  - Training VGG ~150,000 flops/ data byte
- R^3 / R^2 → Volume (compute) / Surface(IO BW)
  - Significantly higher for Deep Nets
- Power dissipation challenges
  - Compute density limited by DC cooling capacity
  - At 1 ~uW / MHz (current state-of-art in 28 nm) requires 300 Watts!

AI is no longer bored ☺

Neural Net Computations

- All Deep Neural Net implementations have the following properties
  - Small set of non-linear transforms
  - Small set of linear algebra primitives
  - Relatively modest dynamic range of weight/data values
  - Very regular/repetitive data flows
  - Only persistent memory requirement is for weights
    - Updated while learning, fixed for recognition

- Variance in the size of the net across applications is $>10^5$

Compute cycles will be commoditized; not computers!

Why minds.ai?

"…around 2008 my group at Stanford started advocating shifting deep learning to GPUs (this was really controversial at that time; but now everyone does it); and **I'm now advocating shifting to HPC (High Performance Computing/Supercomputing) tactics for scaling up deep learning. Machine learning should embrace HPC. These methods will make researchers more efficient and help accelerate the progress of our whole field."** – Andrew Ng, Feb 2016

Neural Network Design Expertise + HPC Design Expertise + Image and Video Recognition Expertise + GPU Programming Expertise

minds.ai was founded on the basis that Deep Learning is the next frontier for HPC – it's what we do

7 levels of parallelism

- Instruction level – SIMD, VLIW etc.
- Thread level – warps
- Processor level – many cores
- Server level – many GPUs in a server
- Cluster level – many servers with high BW interconnect
- Data Center level
- Planet level ☺

ASICs for DNNs

- Exponential growth in Data Centers
  - Commoditization of Enterprise silicon
  - Traditional mobile players announcing ASICs for enterprise compute
- Higher demands for compute density
  - GPGPUs have won the first round
  - Dennardian scaling is breaking down
- Power dissipation will emerge as major challenge
  - Chip level, server level and DC level

Age of dark silicon

Transistor property	Dennardian	Post Dennardian
# of transistors (Q)	S^2	S^2
Peak clock frequency (F)	S	S
Capacitance (C)	1/S	1/S
Supply Voltage (V_{dd})	$1 / S^2$	1
Dynamic Power ($QFCV_{dd}^2$)	1	S^2
Active Silicon	1	$1/S^2$

* S is the ratio of feature size between next generation processes

Heterogeneity in Enterprise silicon

- Dark silicon will drive heterogeneity
  - Multi core architectures with different Instruction Sets
  - Power aware scheduling across cores
  - Decreasing parts of the chip can run at full clock frequency
- Specialized silicon for server blades
  - Bridges to intra server and inter server communications
  - Last level caching support, caching across MPI
  - Distributed compute in network interfaces

7 levels of parallelism

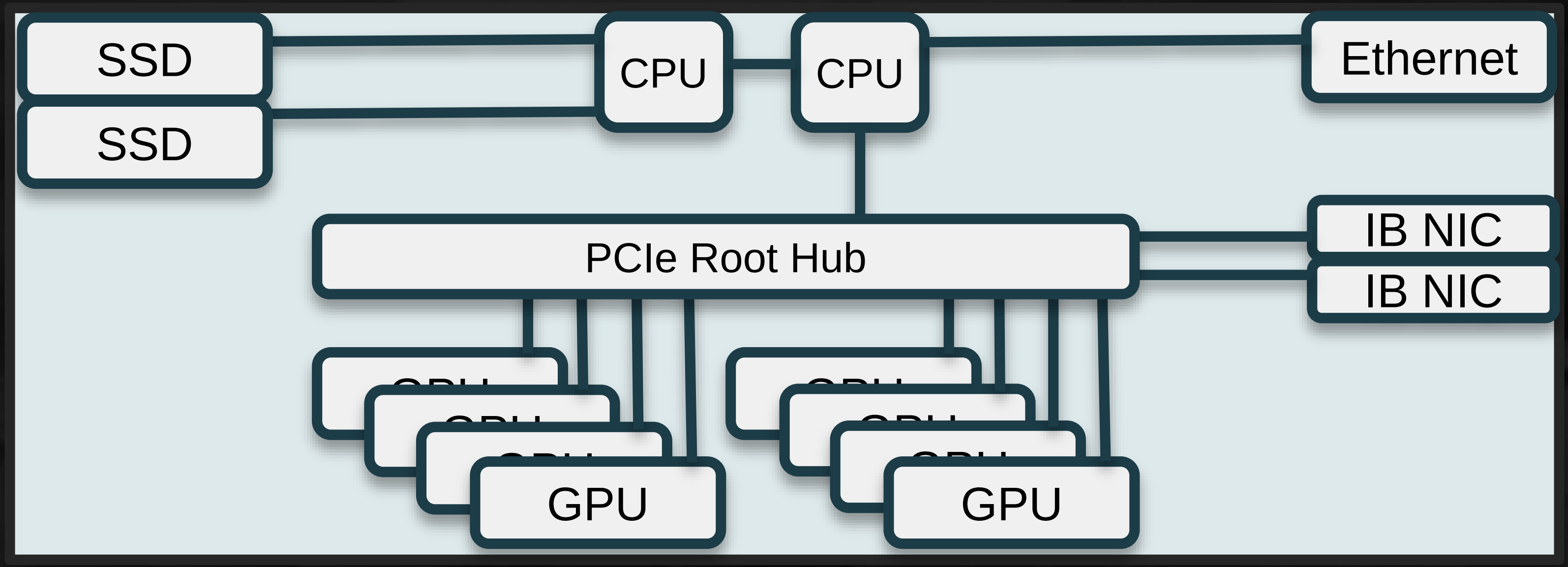
- Instruction level – SIMD, VLIW etc.
- Thread level – warps
- Processor level – many cores
- Server level – many GPUs in a server
- Cluster level – many servers with high BW interconnect
- Data Center level
- Planet level ☺

Heterogeneity in Hyperscale

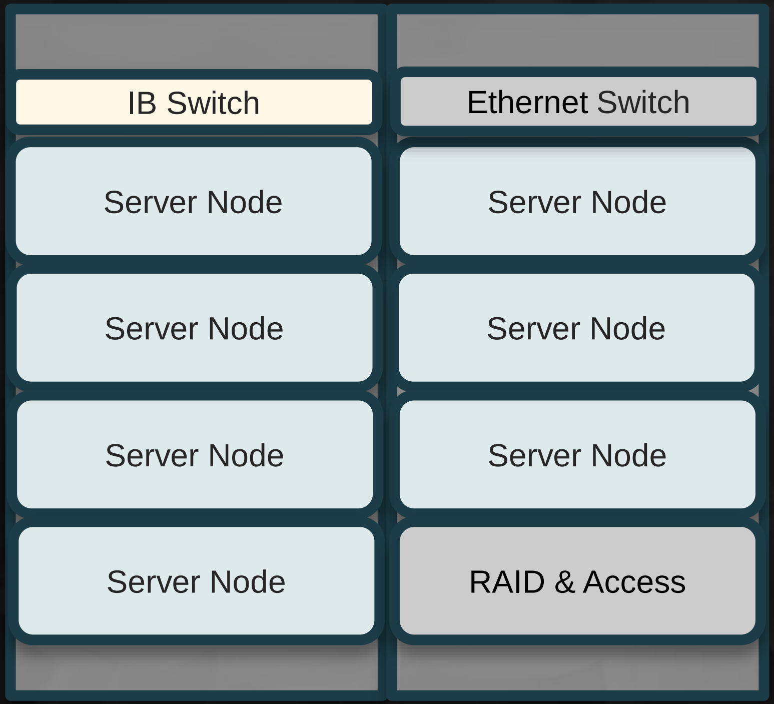
- Deep Learning is driving the convergence of High Performance Compute (HPC) and Hyperscale (Data Centers)
  - Traditional HPC ecosystems : expensive and bleeding edge
  - DC infrastructure : commodity and homogeneous
    - Single or dual CPU servers common
- All of this is changing
  - GPGPUs now common in DCs, initial resistance
  - InfiniBand penetration has reached a tipping point
  - Dense compute clusters require high bandwidth interconnects

Server Architectures

- Intra server vs. Inter server bandwidths
  - Inter server bandwidths will grow faster than intra server
  - Lead to larger, denser servers
    - 8 or more GPGPUs per server for DNN training jobs
    - Will co-exist with CPU based servers for search and database operations
  - Many kinds of servers, one size fits all does not work



Training Server Reference Design



- Scalable up to 7 Server Nodes
- 8 GPUs per Node
- ~2.5kw per Server Node
- 100Gbps IB Interconnect

GPU Training Cluster Architecture

7 levels of parallelism

- Instruction level – SIMD, VLIW etc.
- Thread level – warps
- Processor level – many cores
- Server level – many GPUs in a server
- Cluster level – many servers with high BW interconnect
- Data Center level
- Planet level ☺

Data Center Architectures

- Computing super clusters
  - 10^5 variability in size of compute 'jobs'
  - Large number of collocated servers running the same job
  - High BW, low latency interconnect
  - Clusters could grow to significant fraction of a Data Center
- Architecture of clusters will be hierarchical and heterogeneous
  - Edge servers for security and Data management
  - Dedicated RAID servers
  - Dedicated compute servers
  - Control and management nodes
- Multi DC training clusters for big models are technically feasible
  - Scientific community has performed trans continental simulations

Thank you.

Contacts

- Sumit Sanyal, Founder and CEO
  sumit@minds.ai

- Steve Kuo, Co-Founder
  steve@minds.ai

minds.ai

Accelerated Deep Learning